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Sustainable Concrete by Partially Replacing Coarse Aggregate Using Coconut Shell

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Abstract: A common feature of sustainable buildings is that they drastically reduce emissions, material use and water use and with involvement of economic vitality, environmental, health, and social equity in it. As a whole, the study main concern is the environment and the construction and building technology to enhance natural world as well as building materials. In view to provide new knowledge to the contractors and developers on how to improve the construction industry methods and services by using coconut shells and to sustain good product performance and meet recycling goals, there is need to design a technical specification of concrete using coconut shell as aggregates that will meet the Indian standard requirements in order to help contribute to the industry in saving the environment, to encourage the government to find solutions regarding the disposal to landfills of waste materials and save the environment. The use of coconut by products has been a long time source of income for some people.

Recycling of the disposed material is one method of treating the agricultural waste. The used of coconut shell could be a valuable substitute in the formation of composite material that can be used as a housing construction, such as concrete.

Keywords: Crushed coconut shell, Compressive strength, slit tensile strength, flexural strength, Carbon emulsion, Coconut shell concrete.

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1. INTRODUCTION

Now-a-days many engineers and scientists are in process to find various natural as well as modernized ways for the production of construction materials especially concrete. They are also keen in maintaining its quality and strength and therefore various other materials are used as a replacement of a particular material in the making of concrete. One such material is coconut shell which can be used in concrete making by partially replacing coarse aggregate which is a very important component in concrete. Coconuts being naturally available in nature and since its shells are non-biodegradable in; they can be used readily in concrete which fulfils almost all the qualities of the original form of concrete.

Natural sources are depleting by rapid rate; there should be some way to stop it somewhere. One way to overcome this problem is to replace the coarse aggregates used in the production of concrete by coconut shell which are readily available in nature. Use of this non-biodegradable material in concrete would not only make the construction cost less since coconut shells would require less costing as compared to the coarse aggregates but also re-use the waste material and help in environmental aspect.

A potential exists for the use of coconut shells as replacement of conventional aggregate in both conventional reinforced concrete and plain cement concrete construction. The use of coconut shells as partial replacement for conventional aggregates should be encouraged as an environmental protection and construction cost reduction measure. The increase in population also increases the industrial by- products, domestic wastes etc. It has been noticed in India that coconut shell (CS) as an agricultural waste, requires high dumping yards as well as an environmental polluting agent.

According to Olanipekun E.A [11] et.al. a large amount of agricultural waste which was disposed in most of tropical countries if not be disposed properly it would lead to social and environmental problem. Utilized these disposed material was one method of treating the agricultural waste from waste to wealth.

2. OBJECTIVES

To test the feasibility of utilising coconut shell as a replacement for course aggregate in the construction of concrete.

1.1 To prove that aggregate replaced concretes which are lightweight can be used for structural applications with equivalent strengths to normal weight concrete.

2.2 To make sustainable concrete with more economical for constructions.

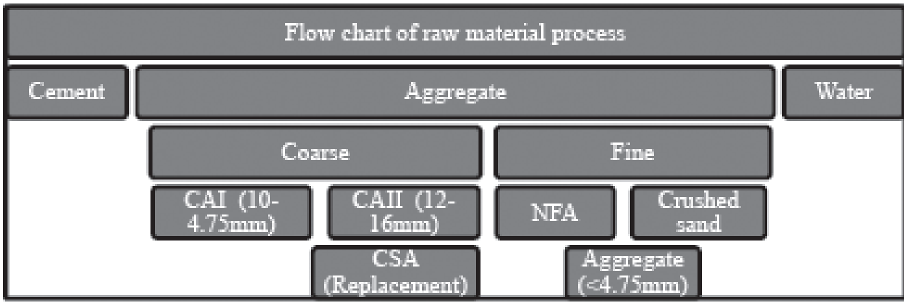

Figure 1: Flow chart of raw material of Coconut shell concrete

There are series of experiments carried out in laboratory as given in Table 1. to ascertain the suitability of coconut shell as course aggregate in concrete with respect to less carbon emulsion, economical cost and ensuring that standard method of assessment are dully followed.

Table 1: Table consists of testing on materials used in concrete

Cement	Coarse Aggregate (Ca)	Coconut Shell (Csa)	Concrete
Standard consistency test	Sieve analysis	Sieve analysis	Workability – slump cone
Initial and final setting time	Absorption	Absorption	Density.
Compressive Strength	impact value	impact value	Compressive Strength.
	Abrasion value	Abrasion value	Flexural Strength. Split tensile strength.

3. EXPERIMENTAL INVESTIGATION

Target mean strength 39.9 N/mm2 concrete was designed as per [4,14] as control mix with natural coarse aggregate. The mix proportion for the above mentioned target mean strength was found to be 1.0: 2.20: 2.20 with w/c ratio 0.38 after the trial mixes. The control mix (CM) was with 100% coarse aggregates (CAII). Other mixes were also prepared by substitution of CA with coconut shell (CSA). The other mixes were 75% CAII + 25% CSA, 50% CAII+ 50% CSA, 25% CAII + 75% CSA and 100% CSA as given in Table 2.

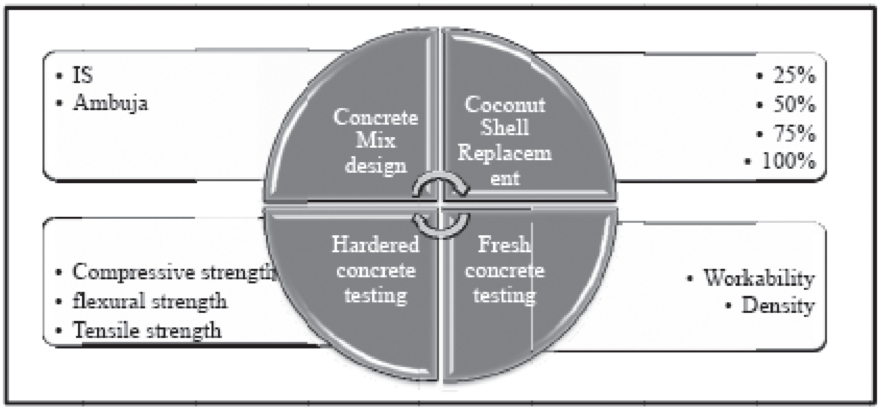

Figure 2: Flow chart of laboratory process

Table 2: Percentage of aggregate used in 5 batches of mixes.

Percentage replacement (CAI i.e. -20mm + 10mm with CSA)					
Code	DM-CS/01	DM-CS/02	DM-CS/03	DM-CS/04	DM- CS/05 (CM)
CAII (%)	75	50	25	0	100
CSA (%)	25	50	75	100	0

Forty five cubes were produced and the densities and compressive strengths were evaluated at 3 days, 7 days and 28 days. Fifteen cylindrical concrete mould of 150mm x 300mm were produced for split tensile strength & fifteen beam of size 400mm x 150mm x 150mm were produced for flexural strength. Properties like compressive strength, split tensile strength, flexural strength were investigated in the laboratory.

The CSA aggregates after crushing and sieving by manual means were presented in Table 2. Physical properties are tabulated in Table 3.

3.1 Material Properties

3.1.1 Cement

Ordinary Portland cement of 53 grade conforming to Indian Standard IS 12269-1987 9 was used throughout the experimental program. The standard consistency was 30.5%, whereas the initial and final setting times were 152

Table 3: Physical Properties of Aggregates & Coconut Shell

	NFA (100%)	CFA (100%)	CAI (100%)	CAII (100%)	CSA (100%)
Bulk Density(gm/m3)	1690	1710	1475	1545	950
Specific Gravity	2.75	2.76	2.77	2.77	1.32
Fineness Modulus	3.69	3.79	7.07	7.04	7.28
Impact Value (%)	-	-	32	35	20
Abrasion Value	-	-	28	30	12
Water Absorption (%)	1.8	2.0	2.1	2.3	27

min. and 213 min. respectively. The specific gravity of cement was 3.14 and its compressive strength after 28 days was 70.6 MPa.

3.1.2 Coarse Aggregate

In this investigation, two types of coarse aggregates were used for preparation of concrete, Crushed Coarse Aggregate. (CAI & CAII) and coconut shell Coarse Aggregate. (CSA)

3.1.2.1 CAI

Crushed hard basalt chips of maximum size 10 mm were used in the concrete mixes. The bulk density of aggregate was 1475 kg/m3 and specific gravity was found to be 2.77.

3.1.2.2 CAII

Crushed hard basalt chips of maximum size 20 mm were used in the concrete mixes. The bulk density of aggregate was 1545 kg/m3 and specific gravity was found to be 2.77.

3.1.2.3 CSA

Available coconut were hammered and crushed to smaller pieces and sieved. The sieved materials were washed with clean water for several times and then dried on sun, made saturated and then required quantity was taken for casting. Physical properties are tabulated in Table No3. The CSA aggregates after crushing and sieving by manual means were presented in Figure 3.

Figure 3: Coconut Shell crushing and sieving by manual means.

3.1.3 Sand

In this investigation, two types of fine aggregates were used for preparation of concrete, Natural fine Aggregate & Crushed Fine aggregate. (NFA & CFA)

3.1.3.1 Natural Fine Aggregate

Natural fine aggregate (NFA) used for this entire investigation for concrete was river sand conforming to zone-I of IS: 383-1970 10.

3.1.3.2 Crushed Fine Aggregate

Crushed fine aggregate (CFA) used for this entire investigation for concrete was manufactured sand conforming to zone-I of IS: 383-1970 10.

3.1.3.3 Water

Potable water conforming to IS 456-2000 11 was used for casting and curing.

4. MIX DESIGN

Mix design were done as per Ambuja Cement Ltd. Concrete mix design method. A proper mix of concrete is essential for the strength of the concrete and better bonding of cement and aggregate. Before the concreting, all the mix materials as per design mix proportions as given in Table 4, Weighed of materials were done as given in Table 5 and kept ready for concreting.

Since the coconut shells are basically wood based and organic material and therefore moisture retaining capacity would be more compared with the crushed stone aggregates. Due to the high water absorption of CSA, the aggregates were pre-soaked for 24 hours in potable water prior to mixing and were in saturated surface dry (SSD) condition during mixing to prevent absorption of mixing water.

Table 4: Proportions of each mix material

	DM-CS/01	DM-CS/02	DM-CS/03	DM-CS/04	DM-CS/05
A/C	4.20	4.20	4.20	4.20	4.20
W/C	0.37	0.37	0.37	0.37	0.37
NFA (%)	25.00	25.00	25.00	25.00	25.00
CFA (%)	25.00	25.00	25.00	25.00	25.00
CAI (%)	20.00	20.00	20.00	20.00	20.00
CAII (%)	22.50	15.00	7.50	0.00	30.00
CSA (%)	7.50	15.00	22.50	30.00	0.00
Chemical Admixture (%)	0.5	0.5	0.5	0.5	0.5

Table 5: Proportions and weight of each mix material by weight.

WEIGHT OF MATERIALS					
CODE	DM- CS/01	DM- CS/02	DM- CS/03	DM- CS/04	DM- CS/05
Cement kg	35.0	35.0	35.0	35.0	35.0
Water Kg	13.0	13.0	13.0	13.0	13.0
NFA kg	36.8	36.8	36.8	36.8	36.8
CFA kg	36.8	36.8	36.8	36.8	36.8
CAI kg	29.4	29.4	29.4	29.4	29.4
CAII kg	33.1	22.1	11.0	0.0	44.1
CSA kg	11.0	22.1	33.1	44.1	0.0
Admixture (gms/ m3)	12.5	12.5	12.5	12.5	12.5

5. TESTS ON FRESH CONCRETE

In this investigation, the workability tests were conducted on fresh concrete. Workability affects the rate of placement and the degree of compaction of concrete. Target Slump was 100mm for control mix (DM-CS/05). Chemical Admixture was used for achieving the target slump. Slump test were conducted on fresh concrete and the results are reported on Table 6. Graphical are results given in Figure 4

Table 6: Workability test results on fresh Concrete

Code	DM-CS/01	DM-CS/02	DM-CS/03	DM-CS/04	DM-CS/05
Slump in mm	70.0	65.0	60.0	50.0	110.0

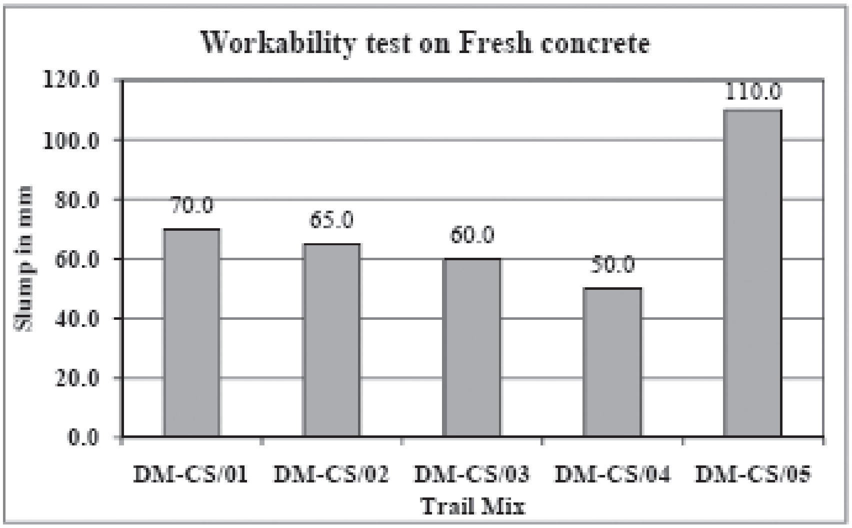

Figure 4: Graphical represent of the slump value for different mixes

6. TESTS ON HARDENED CONCRETE

6.1 Compressive Strength

Three specimens of size 150 mm x 150mm x 150mm were used for compression testing for each batch of mix. Testing of specimens was carried out as soon as possible after curing. The measurements of specimen dimensions were taken before the testing. Cleaned and surface dried specimens were placed in the testing machine. The platen was lowered and touched the top surface of the specimen. The load was applied at the rate of 14 N/mm^2 and maximum load was recorded. The compressive strength of these samples was recorded in Table 7. Graphical results given in Figure 5

6.2 Split Tensile Strength Test

Split tensile test was conducted on cylinders of size 150mm diameter and 300mm height. The testing of specimens should be carried out as soon as

Table 7: Test Results on Hardened Concrete

Code	Compressive Strength in MPa			Split tensile (MPa)	Flexural (MPa)
	3D	7D	28D		
DM-CS/01	22.8	31.3	42.6	1.8	4.1
DM-CS/02	22.6	30.4	41.3	1.7	4.1
DM-CS/03	22.2	29.8	40.5	1.7	3.9
DM-CS/04	18.7	23.3	31.2	0.8	3.0
DM-CS/05	25.6	37.1	50.5	2.1	4.8

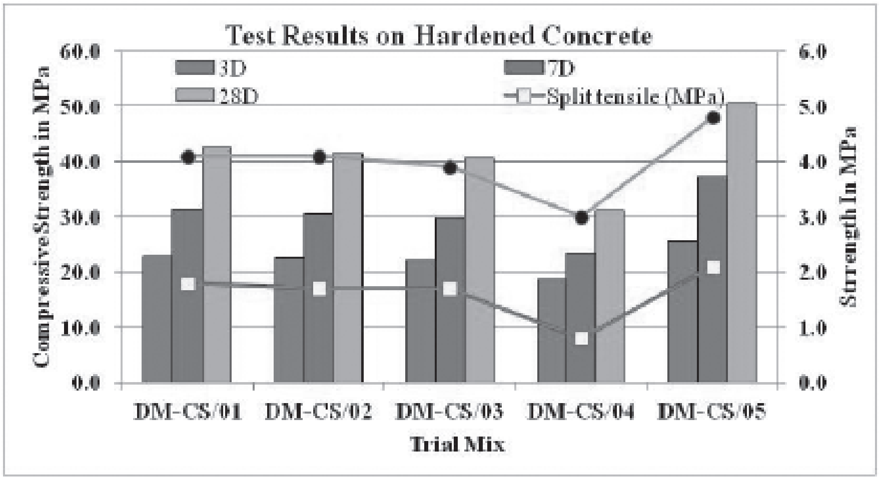

Figure 5. Graphical represent of the Strength value for different mixes

possible after curing. Specimen dimensions were measured before the testing. Cleaned and cured specimens placed in the testing machine. The platen was lowered and was allowed to touch the top surface of the specimen. The force was applied and increased continuously. Maximum load at which the specimen failed was recorded and split tensile strength was calculated and presented in Table 7. Graphical are results given in Figure 5

6.3 Flexural Strength

The prisms were tested to evaluate the flexural strength of the concrete. The prism dimensions were measured accurately before testing and marked by a marker for placing in the testing machine. The test results on hardened concrete are tabulated in Table 7. Graphical are results given in Figure 5.

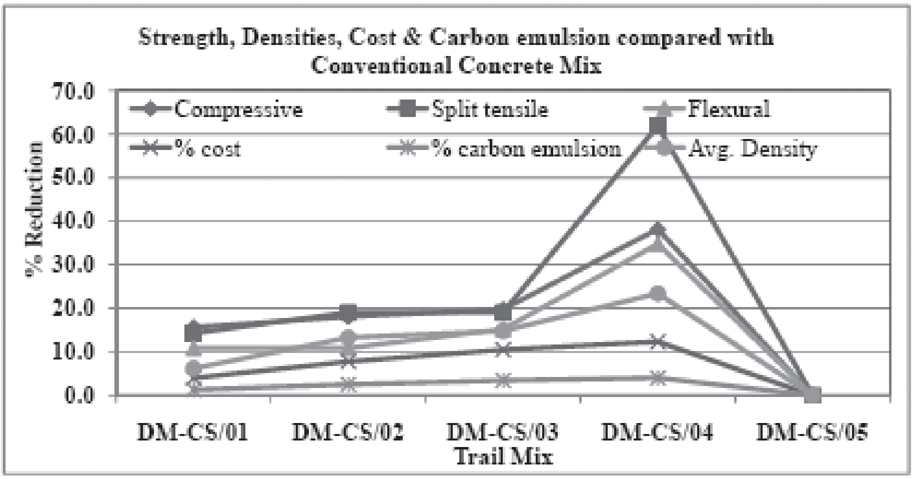

Figure 6: Graphical represent of Reduction in strength, Cost, Carbon emulsion & Densities compared to conventional concrete trials

6.4 Cost Analysis

Cost analysis was carried and compared with each concrete type. It was assumed that the cost of labour and cost of other facility requirements are same for both conventional concrete and CAS based concrete. Therefore, these cost components were not considered in this analysis.

Quantity of the material was determined according to mix proportions. Amount of cement, sand and chips were quantified weight basis. With these

Table 8: Cost analysis of concrete trials

CODE	Rs. Per Kg	DM-CS/01	DM-CS/02	DM-CS/03	DM-CS/04	DM-CS/05
Cement kg/cum	6.85	2911	2911	2911	2911	2911
water Kg/cum	0.06	9	9	9	9	9
NFA kg/cum	1.50	667	617	606	545	711
CFA kg/cum	0.60	267	247	242	267	284
CAI kg/cum	1.00	356	329	323	356	379
CAII kg/cum	1.00	400	247	121	0	569
Admixture	0.02	0.3	0.3	0.3	0.3	0.3
Total cost in Rs..	--	4611	4360	4214	4088	4865
Cost reduction %	--	5.2	10.4	13.4	16.0	0.0

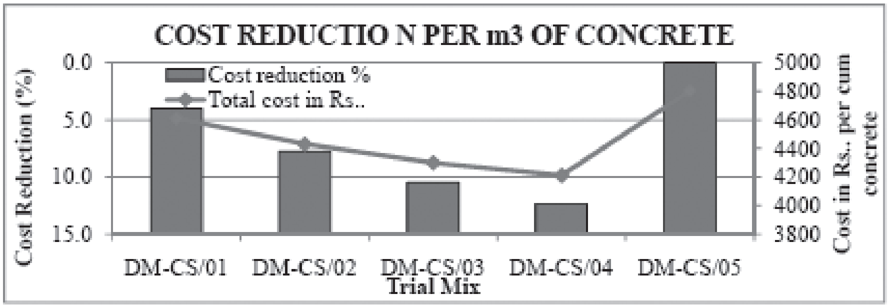

Figure 7: Graphical represent of Cost analysis of concrete trials

prices and material quantities, the material cost of one cubic meter concrete was determined and compared with the material cost of a conventional concrete. No cost was considered for coconut shells since they are freely available.

7. INTERPRETATION OF TEST RESULTS

The test results such as compressive strength, split tensile strength and flexural strength with different proportions of coconut shell coarse aggregate are discussed below.

7.1. Compressive Strength

Compressive strength is the major parameter which influences other properties of concrete. Compressive strength of concrete specimen with natural coarse aggregate (control specimen) was found to be 50.5 MPa. The mix prepared with 25% replacement of CAII with CSA was found to be 42.6 MPa, 50 % replacement of CAII with CSA was found to be 41.3 MPa, 75% replacement of CAII with CSA was found to be 40.5 MPa and that with 100 % replacement of CAII with CSA was found to be 31.2 MPa. From the above test results, it is clear that when coarse aggregate is substituted with CSA, the compressive strength is found to be reducing. This may be due to the fact that the failure of NSC (normal strength concrete) is caused by bond failure of bond between CSA and cement mortar. The bond between mortar and CSA is weaker than that of CAII. The decrease in strength was found to be high and the variation was not linear.

7.2 Split Tensile Strength

Split tensile strength of concrete specimen with 100% CAII was found to be 2.1 MPa. The strength of the mix prepared with 25% replacement of CAII with

CSA was found to be 1.8 MPa, with 50% & 75% replacement of CAII with CSA was found to be 1.7 MPa and that with 100% replacement was found to be 1.1 MPa. The theoretical values of split tensile strength were calculated from ACI-1985, ACI-1992 and ACI-1995. Test results along with theoretical values are plotted in Figure 5. The percentage of reduction of split tensile strength with 0%, 25%, 50%, 75% and 10% CSA are plotted in Fig 6. The split tensile strength was found to be reducing with increase of CSA.

7.3 Flexural Strength

Flexural strengths of concrete specimens with CAII only, with 25% CSA, 50%CSA, 75%CSA and with 100% CSA were found to be 4.8 MPa, 4.1 MPa, 4.1 MPa, 3.8 MPa and 3.0 MPa respectively. The theoretical values of flexural strength were calculated from, IS-456-20007; ACI-1985, ACI-1992 and ACI-1995. Test results along with theoretical values are plotted in Figure 5. The percentage of reduction of flexural strength with 25%, 50%, 75% & 100% CSA were found to 10.9%, 10.9%, 15.2% and 35.8% respectively and plotted in Figure 6. The flexural strength was found to be reducing with increase of CSA. The experimental results are all in good agreement with ACI- 1985 predicted results. Both IS-456-2000 and ACI-1992 overestimate while predicted values by ACI-1995 underestimates. The percentages of overestimation and underestimation are plotted in Fig-.9 From the Fig-.8, it was clear that IS-456-2000 code predicts the test results well.

8. CONCLUSION

From the test results, the following conclusions are drawn

1. Production of Sustainable Light-weight concrete is attained.
2. Carbon Emission observed during aggregate manufacturing is considerably reduced varing from 6%-9% in 50:50 replacements since the quantity of aggregates used is certainly lessened.
3. Overall cost reduction of the construction is observed.
4. Minute Compressive Strength and Flexural strength reduction is observed variably depending on the percentage use of Aggregates and Coconut shells.
5. With 50:50 replacements of Coarse Aggregates-II and Coconut Shells, the strength attained reduces invariably from 10%-20% as compared to the Coarse Aggregate Concrete.
6. With 50:50 replacements of Coarse Aggregates-II and Coconut Shells, the Flexural Strength attained reduces invariably from 10%-15% as compared to the Coarse Aggregate Concrete.

7. The cost reduction in the production of concrete by 50:50 replacements of Coarse Aggregates-II and Coconut Shells varies between 9%-11% as compared to the Coarse Aggregate Concrete.
8. Since minute non-uniform variations are observed in the strength of Coconut Shell Concrete, it can be effectively used for Low Strength Concrete Mixes.

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